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OF OUTER SPACE

REPORT ON THE UNITED NATIONS WORKSHOP ON SPACE TECHNOLOGY FOR RESOURCE DEVELOPMENT AND ENVIRONMENTAL MANAGEMENT, ORGANIZED IN COOPERATION WITH THE GOVERNMENTS OF ECUADOR AND JAPAN

(Quito, 9-13 March 1992)

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INTRODUCTION

A. Background and objectives

1. At its thirty-seventh session, in its resolution 37/90 of 10 December 1982, the General Assembly endorsed the recommendations of the Second United Nations Conference on the Exploration and Peaceful Uses of Outer Space (UNISPACE 82) and decided, among other things, that the United Nations Programme on Space Applications should promote the establishment and strengthening of regional mechanisms for cooperation in the fields of space science and technology and their applications, as recommended by UNISPACE 82.

2. The United Nations Workshop on Space Technology for Resource Development and Environmental Management was one of the activities of the Programme for 1992 that were recommended by the Committee on the Peaceful Uses of Outer Space and subsequently endorsed by the General Assembly in its resolution 46/45 of 9 December 1991. The Workshop was organized in cooperation with the Governments of Ecuador and Japan and was hosted in Quito by the Centro de Levantamientos Integrados de Recursos Naturales por Sensores Remotos (CLIRSEN), from 9 to 13 March 1992, for the benefit of participants from developing countries of the Economic Commission for Latin America and the Caribbean (ECLAC) region.

3. The objectives of the Workshop were: (i) to expose the managers of natural resources programmes and the planners of national development and environmental protection to the possibilities of utilizing data from current and future Earth Observing Systems in their decision-making processes; (ii) to familiarize participants with the functions of the newly established CLIRSEN-Cotopaxi satellite receiving station; and (iii) to provide a forum to discuss and formulate possible regional cooperation programmes that would enable the utilization of the capabilities of the station by the 22 countries covered by it.

4. The goals of the Workshop were met through a number of technical presentations and working group discussions. The presentations addressed the issues related to the acquisition, processing, analysis and archiving of satellite data and included examples of the information that can be derived from the satellite images for specific applications. The Workshop noted that for countries in the ECLAC region to make rational use of their natural resources and to conduct their economic and social development projects in a sustainable manner, it will be necessary for them to continuously monitor their territories. Emphasizing that Earth observation satellites can provide the most cost-effective means of monitoring vast territories and that for that purpose it is necessary that the operation of the Cotopaxi satellite receiving station be ensured, the Workshop concluded that cooperative funding and operation of the station in an adequate regional or subregional framework is one of the possible alternatives.

5. The present report, which covers the background, objectives, organization, observations and conclusions of the Workshop as well as a summary of the lectures presented, has been prepared for the Committee on the Peaceful Uses of Outer Space and its Scientific and Technical Subcommittee. Participants will report to the appropriate authorities in their respective countries.

B. Organization and programme of the Workshop

6. The participants in the Workshop were remote-sensing experts and high-level decision-makers from the ministries of natural resources, economic planning or research institutions in their respective countries. The Workshop was attended by 60 experts from the following 21 Member States and 3 international organizations: Argentina, Barbados, Bolivia, Brazil, Canada, Chile, Colombia, Costa Rica, Dominican Republic, Ecuador, Guatemala, Jamaica, Japan, Mexico, Panama, Paraguay, Peru, Suriname, United States of America, Uruguay, Venezuela, the Food and Agriculture Organization of the United Nations (FAO), the European Space Agency (ESA) and the United Nations (Office for Outer Space Affairs); 44 of these participants represented 18 developing countries from the ECLAC region. In addition, 38 participants from 15 national institutions in Ecuador attended as observers and benefited from the presentations and discussions.

7. The funds provided by the Government of Japan were used to defray the cost of international air travel and per diem of 32 participants from 17 developing countries of the ECLAC region. The Government of Ecuador, through CLIRSEN, provided conference facilities and local transportation for all participants in the Workshop.

8. Opening addresses were presented by Mr. Adigun A. Abiodun, Expert on Space Applications on behalf of the United Nations; Mr. Kiichi Itabashi, Ambassador of Japan to Ecuador; and Mr. Aníbal Salazar A., Director, Instituto Geográfico Militar and President of the Governing Board of CLIRSEN, on behalf of the Government of Ecuador.

9. The programme of the Workshop was developed by the United Nations in consultation with CLIRSEN. The Workshop was conducted through a number of plenary and working group sessions. At the latter, the participants discussed the issues associated with the use of remote sensing for the rational exploitation of natural resources, management of the environment, sustainable development in general and regional cooperation, particularly regarding the acquisition and utilization of satellite data.

I. OBSERVATIONS AND RECOMMENDATIONS

10. The deliberations of the Workshop were conducted through two working groups which focused on the following topics: (i) regional cooperation issues associated with the availability and acquisition of satellite data; and

(ii) programmes, projects and actions to strengthen the use of space technology in the development of natural resources and to assist in the management and protection of the environment. The observations and recommendations that were made by the Workshop on each of these two topics are presented below.

A. Regional cooperation in satellite data acquisition

Observations

11. The Workshop emphasized that for countries in the ECLAC region to be able to achieve and maintain efficient control over the use of their natural resources within a framework of sustainable development and changes in the environment, it will be necessary for them to monitor their territories continuously. The use of satellite data in remote-sensing applications, particularly when it includes the support of Geographic Information Systems (GIS), is a powerful tool that would make this monitoring possible.

12. The availability of satellite data and the information that can be derived from it is essential for the evaluation, management and planning of the use of renewable and non-renewable resources as well as to determine the environmental impact resulting from their exploitation. Consequently, access to satellite data that can be used in remote-sensing applications and other ancillary tools should be ensured, since they are valuable means for national social and economic development.

13. There is a large and diverse amount of information on the territories of countries in the Latin America and Caribbean region. However, this information, which is contained in data banks, reports, satellite images and in thematic maps (derived from a variety of sources), is found dispersed among various user agencies and often in formats that are difficult to integrate in studies aimed at evaluating the changes in values or states of regional and global parameters.

14. In order to determine change, it is necessary for countries to establish a baseline by which they can make comparisons. Such a baseline would contain information, for some date(s), on the state of the environment (land, ocean and atmosphere), urban and rural developments, road networks and other large public works infrastructure. Countries that do not have such information on these or other relevant variables, or where the information is incomplete, should proceed to acquire same, as a matter of priority. The establishment of such a baseline at the earliest possible date is of the greatest importance since the historical record is being lost on a daily basis.

15. It is also important that countries in the ECLAC region have their own means of evaluating national and regional environmental changes, particularly those that could be related to changes of a global nature. This would enhance the contributions of the region to issues such as those addressed by the International Geosphere-Biosphere Programme (IGBP/Global Change).

16. The availability of data and of the hardware and software to process and analyse them is not sufficient to ensure their useful utilization. An indispensable issue that needs to be addressed simultaneously is the development of cadres of professionals that are well educated and trained in the fundamentals of remote sensing and its applications.

17. Because many of the issues to be addressed are of a regional or global nature, the international scientific community as well as Governments and international organizations should support actions leading to the development of the capabilities indicated above.

Recommendations of the Workshop

18. The countries of the region should contribute to the establishment of a number of regional databases containing historical and current satellite data and cartographic information on environmental parameters. These databases would be linked in a network to form a continental database.

(a) The data and information should include those obtained by any type of remote-sensing platform (aerial/satellite), those obtained by various atmospheric probes and relevant parameter values determined from ground measurements;

(b) In locating the required data and information, particular attention should be devoted to the satellite receiving infrastructure of the region, such as that available at the stations at Cotopaxi, Ecuador, and Cuibá, Brazil, in order to ensure the continuous availability of data over the countries under the coverage of their antennas.

19. In connection with the above recommendation and on the basis of the discussions among the Workshop participants, the Government of Ecuador made the following statement:

> "The Government of Ecuador recognizes the importance for each country to gain access to the information it needs in order to undertake adequate natural resource development and environmental management actions at the national, regional and international levels.
>
> "In order to accomplish the above, the Government of Ecuador hereby offers to cooperate with all the countries within the coverage area of the Cotopaxi ground station. Such cooperation, with its financial implications, can be achieved through appropriate consultations with the Governments of these countries. The end result of these consultations should witness an agreement with all these countries, as well as ensure a continuous operation of the Cotopaxi Station and the acquisition and delivery of data to these countries. As soon as possible, the Government of Ecuador will request the United Nations to assist in ensuring that such a cooperation agreement is attained."

20. The continental database referred to above should be established at a number of centres in the region in order to make maximum use of the existing infrastructure. These centres should be linked to form a network that makes it possible both to distribute global data and to update or add regional data. The use of Geographic Information Systems in the establishment and operation of the database is essential; the use of a GIS would greatly facilitate adding new data and information while making it possible to work with various sets of data at the scales that might be needed for specific applications.

21. The data and information contained in the database should be available to the entire region. However, the use of these data and information would not be limited to regional applications only, but could also be used for national purposes, and the results of such utilization would not necessarily have to be transferred to the database.

22. There needs to be a greater number of activities to promote awareness and disseminate information on satellite remote-sensing technology in the region, particularly concerning its potential use in natural resources and in management of the environment. The support of the United Nations and other regional/international organizations would be crucial to this effort and could contribute to the achievement of other specific goals, i.e., the establishment of a fund to finance research-and-applications projects in the area of natural resources and the environment.

B. Space technology for development of natural resources and protection of the environment

Observations

23. There is a strong interest in the region to increase and strengthen education and training in space science and technology. In order to meet current and future demands in the exploitation of natural resources within the concept of sustainable development and for the protection for the environment, subjects dealing with remote sensing and GIS need to be included in the education programmes at the undergraduate and graduate levels. Additional efforts would also be needed for adequate training of scientists, technicians and planners.

24. The region also has a significant number of individuals educated and trained in remote sensing and the use of GIS, although the number of such individuals in the Caribbean subregion is low. In the same subregion, the infrastructure to utilize these technologies is weak and the resources needed to acquire data, materials and equipment are scarce.

25. The Workshop noted that with the increased international awareness of the issues on sustainable development dealt with by the United Nations Conference on Environment and Development there would be a number of opportunities to participate in national, regional and international programmes or projects

related to the protection of the environment. Many of these programmes or projects would qualify for financing from new international sources such as the Global Environment Facility (GEF), which is administered by the United Nations Development Programme (UNDP), the World Bank and the United Nations Environment Programme (UNEP).

26. Regional workshops serve the purpose of updating knowledge in space science and technology and enable participants to become aware of the latest international developments in their field of interest. These workshops also serve to create and strengthen contacts among colleagues with common objectives in the Latin American and Caribbean region. Such contacts are conducive to greater horizontal cooperation and to the transfer of technology and know-how among countries with similar levels of technological development.

27. On the basis of its discussions, the Workshop found an interest and willingness among the participants to work within a framework of regional cooperation. While recognizing that there might be others, the participants identified the following general application areas as those that would be of highest interest to the countries of the region:

- Regulation of rural and urban land;
- Evaluation and monitoring of environmental and cultural impact of development projects;
- Monitoring of protected zones;
- Biodiversity;
- Climate change;
- Diagnosis of degradation of soils and resources;
- Management of natural resources;
- Studies of basins as working units;
- Oceanography, marine resources and aquaculture;
- Deforestation and desertification;
- Land use;
- Natural disasters;
- Use of radar for cartographic purposes;
- Databases for natural and geologic resources.

Recommendations of the Workshop

28. The Workshop endorsed the United Nations initiative to establish a Centre for Space Science and Technology Education in the ECLAC region as an efficient way of preparing the necessary cadres of professionals in remote sensing and related fields. However, it indicated that more than one centre is needed, taking into account both the size of the region and the distances and various languages involved. At the same time, existing centres which act, or could act, as regional training centres should also be strengthened.

29. Horizontal cooperation among the countries of the Latin America and Caribbean region should be increased. This type of cooperation should aim particularly at assisting countries from the Caribbean subregion to educate their professionals and to provide the means for their participation in regional projects.

30. Adequate and efficient channels for the exchange of information on research or applications projects should be created in order to strengthen the coordination of activities.

31. A catalogue of professionals in the areas of remote sensing should be established. Such a catalogue should be easily accessible to the researchers and users of the region and should include an updating mechanism.

32. Greater efforts should be exerted towards providing access to or developing basic educational materials in the local languages. Likewise, additional efforts are needed to provide the scientific community with access to specialized bibliographic materials.

33. The Workshop identified the following specific projects, programmes or activities as those in which the participants, their institutions and, if appropriate procedures were followed, their countries, would have the greatest interest:

(a) A programme for education and training in remote sensing and associated fields for the Caribbean subregion;

(b) An education programme on the fundamentals of remote sensing and satellite meteorology with particular emphasis on the analysis and interpretation of satellite images;

(c) The establishment and operation of a roving workshop to provide local training and updating of skills in remote sensing. Such a workshop could utilize the capabilities of established centres such as the Instituto Nacional de Pesquisas Espaciais (INPE), the Instituto Geográfico Agustín Codazzi (IGAC) and CLIRSEN;

(d) A regional programme to develop applications of low-resolution satellite data;

(e) A regional programme on climatic changes, compatible with the objectives of IGBP;

(f) A project to analyse the various processes of deforestation;

(g) A programme for regional monitoring of hydrographic basins and areas adjacent to large waterways;

(h) A project to establish a Latin American network to exchange information on the use of remote sensing for the management of natural resources and environmental protection;

(i) Activities related to the use of Geographic Information Systems in areas such as protection of indigenous lands and resources in the Amazon region, evaluation of environmental impact of mining projects and others;

(j) Monitoring of oceanographic and climatic parameters for fishing purposes.

34. Regarding the mechanisms to implement the above recommendations, the participants supported previous initiatives for regional and international cooperative actions such as those proposed by the First Space Conference of the Americas, held in Costa Rica in 1990. The participants indicated that many of the recommendations of the current Workshop had already been proposed at that Conference and that the status of their implementation should be reviewed with the aim of pursuing it further.

II. SUMMARY OF PRESENTATIONS

A. Remote sensing in natural resources and environmental management

35. Space technology, in particular remote sensing, has become a powerful tool for resource and environmental management. This is due to the possibilities it provides to conduct observations over an area on a repetitive basis (multi-temporal capability), utilizing various portions of the electromagnetic (EM) spectrum (multi-spectral capability) and with a wide geographic coverage on a regional or even global scale.

36. These capabilities can be particularly useful for planning and monitoring the evolution of national development programmes in cases where topographic or thematic maps do not exist. The use of remote sensing is also very useful over areas with a rapid change in land use, including the effects of deforestation and urban sprawl. In such cases a large gap develops between the real status of resources and the environment and the situations that were originally contemplated when the plans were conceived. Since these plans are often for mid-term enterprises (e.g., for five-year plans), the disparity between reality and the master plan can lead to disastrous results.

37. Remote sensing is often used as an auxiliary tool to provide information in cases where frequent measurements are required or over large and/or inaccessible areas. An example of a practical application is the current use of remote sensing in the preparation of Japan's National Survey on the Natural Environment. The Survey is conducted every five years, in compliance with Japan's Nature Conservation Law of 1972. In earlier years, the Survey was carried out primarily by direct observations made on the ground by about 100,000 volunteers. Due to shrinking budgets, since 1988 remote sensing has been utilized to update the actual vegetation map. Through the use of multi-temporal images, changes in vegetation cover or pattern are detected and the affected areas identified. Ground survey crews are dispatched only to the areas where the change has occurred; this has brought with it a considerable reduction of the budget necessary to conduct the Survey.

38. One of the roles that remote sensing can play is that of providing accurate information that can be used as feedback, at suitable intervals, during the execution of a programme to allow the managers to adjust to the changing conditions. Satellite data are even more useful when integrated with other types of data in a Geographic Information System. A GIS is a database containing data from diverse sources (satellite images, cartographic maps, aerial photos, tabular reports) over the same area and a query language that allows the user to relate them within a geographic context.

39. The combined use of these two tools makes possible the analysis of relationships that exist between a complex set of factors. Such relationships often need to be considered in cases such as the selection of land suitable for a particular type of agriculture or the elaboration of maps of hazard risk areas. In the latter case, maps can be elaborated which identify various degrees of risk for floods, forest fires, landslides and natural or man-made erosion areas. This knowledge is indeed a very valuable asset to the planner in allocating the available resources where they are most likely to be needed or to take preventive actions.

40. On a regional or even global scale, satellite data make it possible to monitor the advance of deserts by determining the amounts of green vegetation at the continental level on a seasonal basis and the displacement of the border of the desert with the vegetation throughout the passage of several seasons.

41. Global data sets now exist or are being put together on global chlorophyll distribution, global cloud volume, world weather records, a world soils map, a global digital elevation model of the surface of the Earth, a global land use map, a world river systems map, world population maps and various other global parameters. Although not all of these data sets are now in digital form that could be easily integrated into a GIS, a number of projects are under way to make this possible.

42. The problems associated with the utilization of resources and management of the environment are mostly related to the pressures exerted by a growing population and by industrial development. These pressures manifest themselves

in various forms in different parts of the world. Through improperly planned resource management or through lax industrial pollution controls, the demands of modern civilization result in over-exploitation and degradation of that same environment that provides the resources and determines the quality of life. In many cases, the lack of up-to-date and accurate information is one of the main contributing factors in bad policy or managerial decisions.

43. Thus, beyond the usefulness of space technology for national development planning, and in order for each country to preserve its environment, a future global remote-sensing database used in combination with a global GIS could make it possible not only to evaluate the human impact on the Earth's environment, but also to develop a global land-use plan on how mankind can achieve a sustainable utilization of the Earth's resources while protecting its environment.

44. Some of the major areas in which remote sensing can provide the information needed to make appropriate decisions are the following:

(a) Land resources: mainly in connection with food production, and covering aspects of soil suitability, erosion, wastelands and desertification;

(b) Forest resources: particularly related to deforestation, fuel-wood supply, shifting cultivation, biomass burning and conservation of various types of vegetation (e.g., mangroves);

(c) Water resources: including evaluation of the expected impact of dam construction for hydroelectric power generation, irrigation projects, surface- and groundwater evaluation and flooding;

(d) Mineral resources: particularly to reduce exploration costs and to plan mining operations that result in minimal environmental degradation;

(e) Marine resources: for monitoring of coastal/offshore pollution and the transport of sediments as well as for locating upwelling areas and areas of potential use for aquaculture;

(f) Global environment: to conduct studies on global warming, sealevel rise, ocean/atmosphere interactions affecting current circulation and to monitor the quality of air, water and land.

B. Availability and acquisition of satellite data

45. The satellite data necessary for remote-sensing applications in any of the areas indicated above are received by a number of ground stations located in various countries around the world. The most recent of these ground receiving stations was established at Cotopaxi, near the city of Quito, and began operating in 1990. After only a short period of time, due to financial reasons, the station greatly reduced its operations and currently its capabilities are largely unutilized.

46. The Cotopaxi Space Station is located at 0° 37' 21" S latitude and 78° 34' 46" W longitude at an altitude of 3,567 metres above sealevel. The Station's coverage area includes 22 countries, from the south of Mexico, most of the Caribbean countries, all of Central America, Venezuela, Guyana, Colombia, Ecuador, Bolivia, Peru, the north of Chile and large parts of Brazil. The Station has been designed to receive, record and process data from the following three Earth observation satellites: (i) Landsat-5, including its Multi-Spectral Scanner (MSS) and Thematic Mapper (TM) sensors; (ii) SPOT 1 and 2, from both of their multi-spectral HRV (High Resolution Visible) sensors; and (iii) ERS-1, from its Synthetic Aperture Radar (SAR) and other microwave sensors.

47. Together, these satellites provide data obtained in the visible, infrared and microwave regions of the EM spectrum, at spatial ground resolutions ranging from 10 m to 80 m. Of these satellites, both Landsat and SPOT have been operational for a long time and the details of their orbits, frequency of revisit, spectral bands and other characteristics, which were presented at the Workshop, are well known and therefore not included in the present report. The characteristics of ERS-1, the first radar satellite intended for operational use by the research and applications communities, are described in some detail below.

48. Functionally, the Cotopaxi Station consists of the Data Acquisition System (DAS), the Recording and Playback System (RPS) and the Data Processing System (DPS). Data can be acquired from Landsat, SPOT or ERS-1 in real time by the DAS unit at data transmission rates of 105 megabytes per second and subsequently recorded on high-density digital tapes (HDDTs). The data is then formatted and passed to the Data Processing System where quick-look products and computer-compatible tapes (CCTs) are produced.

49. The DPS operations are performed by four software packages which can be run on any of three workstations and provide the following types of user products: (i) quick-look micro-images, primarily utilized to estimate cloud cover; and (ii) either raw or geo-referenced radiometrically and geometrically corrected images at full resolution. The products can be provided in digital form in either CCT form or in 3.5-inch, 5.25-inch, and 8.0-inch diskettes. Photographic representations of the images can be provided at various scales in black-and-white or colour form.

50. There are a number of other Earth observation satellites which, although not received by the Cotopaxi Station, also provide data that can be utilized for the development of natural resources and management of the environment. Among these, Japan's MOS-1 satellite, launched in 1987, provides images in the visible and near infrared at a resolution of 50 m. With a revisit period of 17 days, MOS-1 also provides low-resolution data in the visible (0.9 km) and the thermal infrared (2.7 km).

C. Meteorological satellite data for remote-sensing applications

51. Since 1960, when the first meterological satellite (Tiros-1), was launched by the United States, more than 100 meteorological satellites have been launched by several countries and an international organization. As technology has developed, meteorological satellites have evolved from carrying broad-band and low-resolution (tens of kilometres) thermal infrared sensor cameras, to recent ones that carry on board an array of sensors operating in several regions of the EM spectrum and with resolutions on the order of 1 km.

52. Meterological satellites are classified according to their orbits as being either geostationary or polar-orbiting. Geostationary satellites are positioned over the equator at an altitude of approximately 36,000 km. At this altitude their period of rotation coincides with the rotation period of the Earth; this allows these satellites to remain essentially fixed over the same spot of the surface of the Earth. The images from these satellites are primarily used to observe the life cycles of weather systems and thus for forecasting and early warning purposes.

53. Polar-orbiting satellites circle the Earth in polar orbits (i.e., from north to south) at altitudes of 800-900 km. Their period of revolution is on the order of 100 minutes and they provide global coverage twice every 24 hours. These satellites provide coverage over the polar regions, which are not covered by the geostationary satellites. The Meteor (operated by the Russian Federation) and the NOAA-N (operated by the United States National Oceanographic and Atmospheric Administration (NOAA)) series of satellites are examples of polar-orbiting satellites.

54. The NOAA-N satellites carry on board an Advanced Very High Resolution Radiometer (AVHRR) sensor that was designed for meteorological purposes and is now widely utilized for remote-sensing applications. A particularly useful application of the data from this sensor is found in producing "green vegetation index" images at continental or global scales. Such images provide a graphic representation of the amount of green biomass present at various times of the year.

55. Under normal circumstances, the geostationary network of satellites which collectively cover the entire surface of the Earth consists of five satellites: two GOES (East and West) satellites, located at 75° W and 135° W respectively, and operated by the United States; Meteosat, located at 0° and operated by the European Organization for the Exploitation of Meteorological Satellites (EUMETSAT); Insat, located at 74° E and operated by India; and GMS, located at 140° E and operated by Japan. At present, only one of the GOES satellites is functional, and is located at 108° W. In a coordinated action, Meteosat has been displaced to a location of 50° W in order to minimize the gap in coverage.

D. Radar satellite data for remote-sensing applications

56. Radar systems are a type of sensor that has recently started to become operational for use in research and applications related to the Earth's natural resources. Radar sensors operate in the microwave region of the EM spectrum and generate their own illuminating radiation. The reflected portion of this radiation is received by the radar sensor system, converted into digital values and transmitted to Earth for their subsequent processing and analysis.

57. The spatial resolution attainable from a radar system is independent of the altitude of the sensor platform and increases with the length of the antenna that transmits and receives the microwave pulses. Synthetic Aperture Radar applies a linear frequency modulation to a transmitted long pulse in order to simulate a train of short pulses. Combined with the motion of the satellite, the technique performs a modified data processing on this modulated pulse and on the Doppler shift of the reflected pulse, to simulate a much longer antenna. The result is a higher resolution which is only limited by the power that the antenna is capable of transmitting.

58. The microwave spectrum has been subdivided into various bands, each of which is referred to by a single letter and is determined by a specific range of frequencies, as follows:

Band name	Band limits (Ghz)	Band name	Band limits (Ghz)
P-band	0.225-0.390	K-band	10.90-36.00
L-band	0.390-1.550	Q-band	36.00-46.00
S-band	1.550-4.200	V-band	46.00-56.00
C-band	4.200-5.750	W-band	56.00-100.00
X-band	5.750-10.90		

59. Launched in July 1991, ERS-1 is a low-orbit Earth observation satellite with several microwave sensors on board. The primary mission of ERS-1 is to increase the understanding of ocean processes, to monitor the polar regions and to contribute to the World Climatology Research Programme. However, an increasing number of land-oriented applications will soon result as the international research community gains access to the data. The primary instrument on board ERS-1 is the Active Microwave Instrument (AMI), which can provide high-resolution images (C-band), wind speed through ocean wave spectra analyses and the length and direction of ocean waves. Operating in the imaging mode, AMI covers a swath of 80-100 km, with initially assessed resolutions of 27 m in range and 29 m in azimuth. Preliminary assessment through the end of 1991 also shows high precision and replicability of the data acquired by ERS-1.

60. Operating in the wind mode, AMI covers a swath of 400-500 km over the ocean, with resolution cells of 50 km, and measures wind speed in the range of

4-24 m/s. Wind speed and direction are determined by measuring the strength of the back-scattered signal of each resolution element from three directions: obliquely ahead, to the side and obliquely behind the satellite path. The intensity of the three signals provides the wind speed, and the differences between them provide the wind direction with an accuracy of 20°. In wave-mode operation, AMI determines the length and direction of ocean waves in 5 x 5 km cells for segments of 200-300 km along the satellite path. Ocean wavelengths of 100-1,000 m can be measured to an accuracy of 25 per cent and their direction to an accuracy of 20°.

61. In addition to AMI, ERS-1 carries a Radar Altimeter (RA) that operates at a wavelength of 2 cm. This altimeter looks vertically downward to measure average wave height and wind speed and to determine the meso-scale ocean topography. Data from this altimeter will be used to determine ice type and topography as well as the water/ice boundaries. ERS-1 also carries an Along Track Scanning Radiometer (ATSR) that operates in three bands in the thermal infrared region; these bands are centred around 3.7, 11 and 12 μm. ATSR looks through the atmosphere at the surface of the ocean from two directions, downward vertically and at an incidence angle of 50°. The difference between the oblique and vertical measurements provides information on atmospheric absorption, while the differences between measurements at the three wavelengths are used to determine atmospheric water vapour content.

62. For oceanographic studies, the major drawback of visible and infrared images is the extent of cloud cover. A solution to this problem is to utilize data obtained in the microwave (radar) region of the EM spectrum, since the radiation with wavelengths in this range can penetrate through clouds and, to a high degree, through rain. Consequently, radar sensor systems have an all-weather capability to acquire data. Since radar systems generate their own illuminating power, they can also gather data during night-time.

63. Microwave radiation that is transmitted downward by a satellite (or aircraft) radar is scattered back into the atmosphere in all directions. The intensity of the radiation scattered in the direction of the satellite depends on the wavelength of the incident radiation and on the roughness of the ocean surface. The roughness of the ocean surface depends on such factors as wind velocity and even the topography of the ocean floor. Thus, proper analysis and interpretation of the data acquired by the radar systems can provide the values of these and other parameters or physical characteristics of the ocean.

64. Oceanographic phenomena that can be imaged or inferred from radar data include the direction, frequency and speed with which surface waves are travelling. The timely knowledge of this information is of practical value to operational offshore wave forecasting, marine transportation, fishing, naval activities and coastal erosion research. Internal waves are generated by the interaction of tidal currents and abrupt changes in the ocean floor topography. Next to surface waves, internal waves are the most widespread and observed features in SAR images. Other oceanographic phenomena that can be observed in SAR images include eddies which can be seen near strong currents and downstream of points of land, tidal flows, bathometric features and various types of ice.

E. Remote-sensing applications for early warning (climate)

65. Some natural phenomena, such as El Niño, affect climate on a regional or global scale, often with disastrous consequences. In the 1982-1983 episode of El Niño, Peru suffered losses worth US$ 2 billion and a decline of 13 per cent in its gross domestic product. As a result of such consequences, these phenomena have been studied over a long period of time utilizing conventional data-gathering and monitoring methods of their critical parameters.

66. In the case of El Niño, its onset can be monitored to a great extent by determining ocean surface temperature and wind velocity. Under normal circumstances, the sea-surface temperature (SST) of the Western Equatorial Pacific (i.e., adjacent to Australia) is 29° C, while in the Eastern Equatorial Pacific (i.e., adjacent to Ecuador and Peru) SST is 22° C, i.e., there is a thermal gradient of 7° C. Also, under normal circumstances the winds are predominantly easterly. The easterly winds flow west from the South American coast as surface winds until they reach the vicinity of meridian at 165° E. Around this longitude there is an inter-tropical convergence area which, together with the higher water temperature, results in an upward flow leading to cloud formation. At some height, there is a reversal of wind flow direction towards South America; this closes the loop known as Walker's circulation.

67. The onset of El Niño occurs when SST close to the South American coast is higher than normal. This causes a lower velocity or even a reversal of the easterly winds. The weakening of Walker's circulation is accompanied by a rising of the thermocline off the coast of Australia and its deeping off the coast of South America. The anti-cyclonic region in the South Pacific weakens and the inter-tropical convergence zone referred to above is displaced southward. All of this results in an altered atmospheric system with warmer air temperatures in the northern Pacific region of South America, bringing with it associated flooding and drought episodes. Although this phenomenon cannot be prevented, the meteorological and radar satellites described above can provide, at a low cost and in a timely manner, the necessary data for an early warning system.

F. Radar satellite data for environmental applications (forestry)

68. Tropical forests play a major role in the hydrological cycle and in recycling atmospheric carbon dioxide. They stabilize soil and prevent excess run-off of silt and dissolved substances into streams. Their effects on climate through energy and water exchange with the atmosphere are not well understood but are expected to be significant. Much of the diversity of the Earth's species is represented by the plants and animals which make up the tropical-forest biomass.

69. For most tropical countries deforestation has come to represent the drain of an increasingly valuable resource. Local and overseas interests alike have

over-exploited forest resources. While it is apparent that improved management of tropical forests requires substantial economic, political and institutional changes, it also requires additional information about the forests themselves and about the changes which are occurring in and around them. Much of the additional information can be supplied by satellite and airborne remote-sensing systems (with adequate field checking).

70. The development of digital SAR imaging and processing technology during the 1980s has resulted in advanced operational systems that can currently provide spatial resolutions of 27 m, with high geometric and radiometric quality, and will soon be able to provide 10 m resolution in an operational manner. Numerous regional and national tropical vegetation surveys have shown the applicability of radar data to specific types or conditions of vegetation. In particular, major vegetation formations, including savanna, dense and open tropical forest and woodlands, have been identified on radar imagery. Published reports have also shown that mangrove forest environments can be mapped accurately because of their strong radar back-scatter compared to the surrounding forest stands. Radar imaging has also been successfully used for mapping a variety of forest types, including swamp forests, high scrub forest, tea trees, eucalyptus forest and palm forests, as well as pine, banana and rubber plantations.

71. The aircraft of the United States Jet Propulsion Laboratory (JPL), using the C-, L- and P-bands, completed a series of flights over Belize in 1990 allowing for a direct comparison of the usefulness of the three bands for tropical forest applications. The results showed that the image contrast for forested/deforested boundaries increased with wavelength. There is also a decrease in mean reflectivity at C-band wavelengths with increasing angle of incidence of the microwave radiation. This effect could prove useful as a discriminating element for data available over a range of incidence angles, as will be the case of Canada's Radarsat data.

72. Canada's Radarsat will carry one SAR instrument that will also operate in C-band with a multi-mode single polarization. Radarsat will obtain images in swaths of 35-100 km in width with associated resolutions of 10-100 m. This instrument has been designed to have imaging capabilities at a variety of incidence angles (approximately 20°-50°). The spacecraft has been designed for a five-year lifetime and is scheduled to be launched in December 1994. The orbit is planned at 800 km, sun-synchronous, dawn-to-dusk, with a 24-day repeat visit cycle. The SAR antenna will point north but the spacecraft will be capable of rotating 180° about its yaw axis in order to obtain images of Antarctica. Because it will carry on-board tape recorders, Radarsat will be able to provide radar imagery of the entire globe.

73. Although C-band data will be the most abundant data to be obtained from operational systems for the next decade, they are not the best data for tropical forest applications. Results from the limited C-band data available show little discrimination between undisturbed tropical forests and older deforested areas or dense plantations. The results also indicate that C-band radar rarely penetrates through foliage in closed moist forests. Experiments

such as the JPL mission referred to above also show that the P-band has the greatest potential to differentiate between the canopy's foliage, the standing timber and the surface beneath the forest. These differentiations improved when the polarization of the incident and reflected radiation was considered.

G. Geographic Information Systems: a management tool

74. The information derived from each of the various remote-sensing systems is in most cases used for a specific application. Beyond that application, such information can be considered ancillary information or raw data that can be used with other information in a GIS for management and policy-making decisions. The sources of data for a GIS are the following: remotely sensed data, point measurements such as field-obtained data, existing cartography and statistical or census-type information. The important characteristic of a GIS is that all the data contained in it have positional references, usually geo-coded to corresponding points on the Earth's surface.

75. A GIS can be defined as consisting of the following three basic elements: (a) a large amount of data which have spatial or locational characteristics; (b) an integrated set of programmes which distinguishes the GIS from a series of unrelated individual programmes; and (c) a common set of sub-components which perform such operations as data storage, retrieval, analysis and display. From a user's point of view a GIS is a relational type of database, spatially indexed in such a way that new information can be added from external sources or created from existing information.

76. A GIS is visualized as consisting of a number of layers, each of which contains thematic information on one or more variables over the surface area being considered. Through user-defined queries, the system can superimpose all or a subset of the layers to produce an output in the form of a tabular or statistical report or as an image either on a television monitor from which a hard copy could be made or in digital form on magnetic tape to be used to generate a map-like product.

77. A GIS product such as the one indicated above could be used for planning purposes, as, for example, in identifying new agricultural areas for particular types of crops and to locate distribution points for the types of fertilizer that would be required. Another important use for GIS products is as information for predictive models. While these models would not indicate actual future conditions, they would be capable of indicating the conditions that might be expected if a particular trend (e.g., land degradation) continued at the current rate, or if particular climatic conditions occurred (e.g., drought/flooding associated with the El Niño phenomenon). If the appropriate information is input into its database, a GIS can be used to evaluate or predict complex scenarios involving many parameters in a fast and reliable manner. A GIS could be the basis for specialized information systems such as an agricultural information system, a forestry resources information system or an environmental impact information system.

H. GIS applications for early warning (food production)

78. When a specialized information system provides access to multiple users located remotely away from it, the database becomes a powerful tool for planning and management. Since 1976, FAO has been developing the operational use of data from the meteorological and Earth resources satellites to improve the information databases of the FAO Global Information and Early Warning System (GIEWS) on Food and Agriculture and Desert Locust Plague Prevention programme. The system which was developed for this purpose and became operational in 1988 is known as ARTEMIS.

79. In the field of food security early warning and desert locust control, the soil moisture parameters, as derived from precipitation estimates, and the quantity and distribution of green vegetation are key indicators of agricultural production conditions and of the ecological potential for the growth of desert locust populations.

80. Although microwave and thermal remote sensing are both sensitive to soil moisture conditions, neither of these two applications have been developed to a stage where they are operational. At present, the most reliable operational information is obtained from the remote sensing of meteorological events that cause soil moisture changes relevant for agricultural production or that provide adequate conditions for the development of a growing locust population. The ARTEMIS information system utilizes data from Meteosat and from the AVHRR sensor of the NOAA satellites for these two purposes.

81. ARTEMIS is a highly automated, dedicated satellite data acquisition, thematic processing and production system, based on the use of high-frequency Meteosat and AVHRR data. The manipulation and query of ARTEMIS digital products and their combination with data from other sources is performed through the use of the Integrated Land and Watershed Information System (ILWIS), a GIS developed by the International Institute for Aerospace Survey and Earth Sciences (ITC) of the Netherlands.

82. The products provided by ARTEMIS on a daily, 10-day or monthly basis include the following: (i) normalized difference vegetation index maps; (ii) potential breeding activity factor maps; (iii) rainfall anomaly maps; and (iv) crop moisture availability maps. These products are provided routinely to regional and national food security early warning systems in a number of countries in Africa.

83. Rapid communication of the high volume of information involved requires special communications facilities. A dedicated satellite communications system, known as DIANA, based on low-cost microcomputer technology and utilizing the satellites of the International Telecommunications Satellite Organization (INTELSAT), has been formulated by FAO and ESA for this purpose. The use of the DIANA satellite communications system of ESA will permit near real-time transmission of high volumes of ARTEMIS digital data to microcomputer terminals in several countries in Africa.

I. Education in remote sensing and Geographic Information Systems

84. In order to derive maximum benefits from the potentials that space technology offers, a country must have a nucleus of scientists and technicians who have an in-depth understanding of the physical principles involved. At the national level, the education, research and applications capabilities of various institutions could be used in a coordinated manner to enrich the pool of available expertise and resources and to avoid duplication of efforts, particularly in cases where the availability of these elements is severely limited.

85. An approach as indicated above is being followed by Peru, whereby a number of remote-sensing user institutions and universities have proposed to participate in a National Remote Sensing Programme. The Programme would include the activities and resources of the participating institutions, coordinated by a National Executive Council. The Programme would conduct its work through a number of technical committees that would address the various disciplines identified by the Executive Council. One of the first committees to start functioning, with the Comisión Nacional de Investigación y Desarrollo Aeroespacial (CONIDA) as its lead agency, is the Education Committee.

86. On a regional level, the United Nations, through its Programme on Space Applications, has launched an initiative to establish Centres for Space Science and Technology Education in the developing countries. Such centres are to be established in a host institution with existing and renowned education and research programmes. Due to the current concerns with sustainable development and protection of the environment, the centres will focus initially on remote sensing and satellite meteorology education but in a second stage will include all aspects of space science and technology. The participants in the education programme of the centres will be educators, research scientists and applications specialists from the developing countries of the region concerned.

87. The education programme of each centre will last nine months and will provide in-depth education in all areas of the physical and mathematical sciences involved in the utilization of remote sensing and satellite meteorology. The curriculum for these subject areas will be developed by a group of experts from the international community, with a strong representation from the region. This group of experts will ensure that the education programme to be implemented is appropriate to the social and economic conditions of the region and takes into consideration any educational materials that have already been developed within or outside the region. Instruction will be provided by the centre's staff, which will include personnel from the host institution, from relevant institutions of the region and from similar institutions in the industrialized countries or from other regions.

88. Through the Economic Commission for Latin America and the Caribbean, the United Nations invited proposals from Member States of the region to indicate their interest in serving as host to the centre. Four countries (Argentina,

Brazil, Chile and Mexico) have offered to host the centre and have submitted proposals to that effect to the United Nations. The United Nations subsequently conducted an evaluation mission to each of the four countries with a view to determining the viability of establishing a centre in them. The report of the mission is intended to assist in the process of selecting the host country.

89. In preparing for the evaluation mission, the United Nations invited potential donor countries to participate in the mission in order to enable them to better assess the merits of the United Nations proposal, the interest in the region and the viability of the centre as well as to determine the level of their participation in its establishment and operation. The Governments of Canada and Spain accepted the invitation and participated in the evaluation mission along with representatives of the United Nations, the local offices of ECLAC and UNDP and an independent consultant. It is anticipated that the selection of the host country will be concluded in early 1993 and that the Centre will be able to begin its first education programme in the last trimester of the same year.

Annex

PROGRAMME OF THE WORKSHOP

Date	Time	Subject	Speaker
Monday 9 March	9-9.30 a.m.	Opening ceremony:	
		Mr. Adigun Ade Abiodun Expert on Space Applications	United Nations
		Mr. Kiichi Itabashi Ambassador of Japan	Japan
		Mr. Aníbal Salazar A. Chairman, CLIRSEN Directorate	Ecuador
		Chairman: J. Yepez, Ecuador	
	9.30-10 a.m.	Keynote address:	F. Durango Vela CLIRSEN/Ecuador
		Data products and services available for use in national resources and environment programmes: the role of the COTOPAXI Station	
	10-10.30 a.m.	Keynote address:	S. Murai University of Tokyo
		The use of space technology in resource and environmental management: research and policy issues	
	10.45-11.30 a.m.	Mission to Planet Earth/ISY	D. Skole University of New Hampshire
	11.30 a.m.-12.15 p.m.	Characteristics of high-resolution Earth observation satellite data (Landsat, SPOT, MOS)	C. Elizondo IGN/Costa Rica
		Chairman: C. Brockman, Bolivia	
	2-2.45 p.m.	Characteristics of meteorological satellite data (NOAA/AVHRR, GOES, Meteosat)	S. Burton Caribbean Meteorological Institute

Date	Time	Subject	Speaker
	2.45-3.30 p.m.	Potential applications radar satellite data to tropical forest and other environment and natural resource management programmes	K. Raney CCRS/RADARSAT
	3.45-4.30 p.m.	The ERS-1 programme: applications to oceanography and marine/coastal resources	M. Cantón ESA
	4.30-5.15 p.m.	The Satellite Data Collection System: gathering ground-measured data	S. Camacho United Nations
		Chairman: S. Burton, Caribbean Meteorological Centre	
Tuesday 10 March	9-9.45 a.m.	Digital image processing for change detection in environmental applications	Y. Yasuoka Institute of Environmental Studies
	9.45-10.30 a.m.	Principles of Geographic Information Systems (GIS) and applications in resource management	C. Pattillo University Católica de Chile
	10.45-11.30 a.m.	Specialized databases, GIS and communications networks for resource management: the ARTEMIS project	J. U. Hielkema FAO
	11.30 a.m.-12.15 p.m.	Use of GIS in change detection	D. Skole University of New Hampshire
		Chairman: K. Raney, Canada	
	2-2.45 p.m.	Environmental impact assessment of present and future urban development	J. Velez SEDUE/Mexico
	2.45-3.30 p.m.	Use of AVHRR data in monitoring vegetation growth cycles	W. Lawrence NASA
	3.45-4.30 p.m.	Use of GIS in conservation and management of natural resources	J. P. Arce CDC/Bolivia
	4.30-5.15 p.m.	Analysis of the onset and monitoring the effects of El Niño	M. Valverde SENAMHI/Peru

Date	Time	Subject	Speaker
		Chairman: J. Hielkema, FAO	
Wednesday 11 March	9-9.45 a.m.	A National Remote Sensing System: a solution for Peru	R. Coloma CONIDA/Peru
	9.45-10.30 a.m.	Evaluation of natural resources and their preservation	R. Alvarez UNAM/Mexico
	10.45-11.30 a.m.	Regional Centre for Space Science and Technology Education	A. Abiodun United Nations
	11.30 a.m.-noon	Discussion	
	2.15-5.15 p.m.	Visit to the Cotopaxi Satellite Receiving Station	
Thursday 12 March	9 a.m.- 12.15 p.m.	Working groups: objectives of the working groups: 1. To identify areas within (a) natural resources management and (b) protection of the environment, in which the use of satellite data is necessary and cost-effective; 2. To propose programmes, projects or actions, at the national and regional levels, that could provide lasting contributions to the above-mentioned areas; 3. To identify the type of professional and material resources that will be needed and to propose mechanisms of regional cooperation.	
		Working Group A Chairman: C. Brockman, Bolivia Topic: Availability and acquisition of satellite data for the Latin American and Caribbean region	

Date	Time	Subject	Speaker
		Working Group B Co-Chairmen: M. Farias, Chile, and K. Raney, Canada Topic: Programmes, projects and actions to strengthen the use of space technology for resources development and management of the environment	
	2-5.15 p.m.	Working Groups (continued)	
Friday 13 March	9-11 a.m.	Working Groups (continued)	
	11a.m.-noon	Summary and conclusions of the working groups	
	1-5.30 p.m.	Tour of Quito	
	6-7 p.m.	Closing ceremony	